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DEVELOPMENT AND TESTING OF A REACTOR MODEL FOR LOW-TEMPERATURE PYROLYSIS OF BIOMASS

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This article presents test results for a reactor model designed for low-temperature pyrolysis of biomass. The efficiency of the pyrolysis attains maximum values at 240–250°C and a process duration of 50 min. The test results are used in the development of an industrial reactor with a capacity of 1 ton/h with respect to initial biomass.

***Keywords**: biomass, reactor, low-temperature pyrolysis, energy efficiency.*

Low-temperature pyrolysis (torrefaction) of biomass (alternate form of fuel) is applied to processes involving preliminary heat treatment of biomass prior to its incineration, gasification, or combined incineration with fossil forms of solid fuel (coal/lignite). During low-temperature pyrolysis (LTP), the fibrous structure of the biomass is broken down, and the heat value is increased, and the biomass becomes hydrophobic and more resistant to biological action, and retains its properties longer (owing to destruction of the –OH radical) – does not adsorb moisture from the air [1]. This is of particular import for biomass with a low moisture content, for example, straw biomass, which is preferred over wood biomass as a fuel.

The LTP is carried out in an oxygen-free medium at 200–300°C. The LTP products of the biomass are solid biomass residues, liquid products (mainly H_2O), and non-condensable gases (primarily CO_2). The carbon content in the remaining biomass, and, consequently, the heat value of the biomass obtained as a result of LTP increase, and the content of hydrogen and oxygen decrease with increasing temperature and duration of the treatment [2, 3].

The objective of this study is to evaluate the design parameters of a reactor model (Fig. 1) for simulation of biomass LTP – straw granules – for the development of industrial reactors.

The biomass is delivered into the reactor via a charging port. A high-temperature TLV-330 heat-transfer medium is heated in a boiler with a fluidized-bed furnace to 255–265°C, which is ~15°C higher than the temperature within the reactor. An inert atmosphere is provided in the layer of biomass being heated by feeding inert gas (nitrogen) into the layer, or by the gases that are separated from the biomass during heating (primarily CO_2 and H_2O), which displace the air from the spaces between the particles of biomass. The torrefacted granules are cooled to 120°C by water through the wall of the reactor, and are off-loaded from the reactor via a discharge port. The biomass granules are displaced along the trays of the reactor by a paddle mixer. The gap between the paddles and trays of the reactor is adjustable.

The dimensions of the pilot reactor are: internal diameter of 1.2 m; height of reactor (zone of pyrolysis) of 0.806 m; and overall reactor height of 1.84 m. The number of mixer paddles is two; and the rotational speed of the mixer is 1–28 rpm. Paddles with a height of 70 mm are installed at an angle of 30° to the horizontal. The output of the reactor with respect to torrefacted granules is 60 kg/h.

Based on results of preliminary experiments (Figs. 2, 3), the optimal LPT temperature of straw biomass is found to be no more than 250°C. The energy efficiency of the LTP process was calculated for the dry, water-free weight from the equa-

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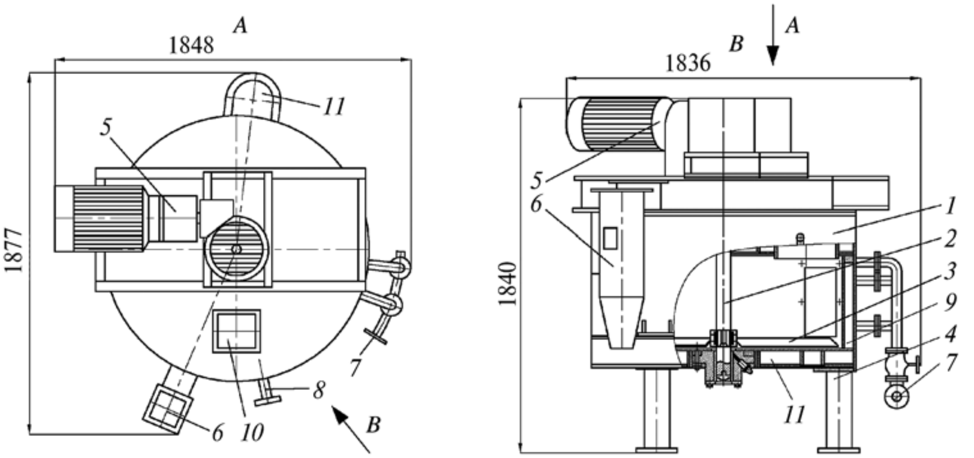

Fig. 1. Laboratory reactor: *1*) shell; *2*) shaft; *3*) paddles; *4*) supports; *5*) drive; *6*) aspiration; *7*) feed of heat-transfer medium; *8*) discharge of heat-transfer medium; *9*) jacket; *10*) charging port; *11*) discharging port.

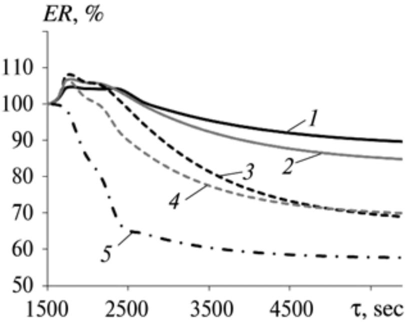

Fig. 2. Dependence of energy efficiency *ER* of LTP process on duration τ and temperature of process: *1*) 240°C; *2*) 250°C; *3*) 260°C; *4*) 270°C; *5*) 280°C.

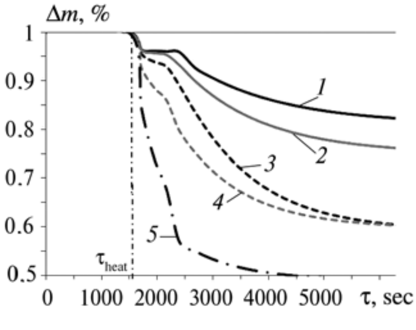

Fig. 3. Dependence of weight loss Δ*m* of specimen on duration τ and temperature of process: *1*) 240°C; *2*) 250°C; *3*) 260°C; *4*) 270°C; *5*) 280°C.

tion $ER = (m_{tor}Q_{tor})/(m_{raw}Q_{raw})$, where m_{raw} and m_{tor} are the weight of the material prior to and after pyrolysis, respectively, in kg; and Q_{raw} and Q_{tor} are the low heat values of the biomass prior to and after pyrolysis, respectively, in MJ/kg. ER values above 100% at the start of the process (see Fig. 2) are not a disruption of the energy balance, since the increase in the heat

TABLE 1

Component	Content, wt.%
Ash	7.48
Carbon	43.1
Hydrogen	5.55
Nitrogen	0.45
Chlorine	0.094
Oxygen	43.7

TABLE 2

Temperature and duration of biomass treatment	Content of elements in biomass, wt.%			Q_{tor}, MJ/kg
	C	H	O	
220°C, 40 min	46.23	5.02	42.76	17.64
240°C, 50 min	50.41	4.1	37.99	19.03

value of the biomass is reflected as a result of the LTP. The *ER* decreases, and tends to a nearly constant value with increasing duration of the treatment.

During the time interval $0 < \tau < \tau_{heat}$, the biomass charged into the reactor is heated to the temperature of the LTP process (see Fig. 3). According to [3], τ_{heat} is assumed to be 1500 sec.

In the LPT temperature region from 240 to 250°C (see Figs. 2 and 3), maximum energy efficiency and minimum weight loss of the sample (~5%) are ensured when the treatment time is no longer than 3000 sec. The chemical composition of the initial straw granules is presented in Table 1; and the low heat value Q_{raw} = 16.67 MJ/kg.

As a result of LTP, the content of carbon and oxygen in the biomass increase and decrease, respectively, ensuring an increase in its heat value. Here, the biomass approaches a fossil fuel in terms of chemical composition, and, consequently, becomes more suitable for combined combustion with a fossil fuel (as compared with the initial untreated biomass (Table 2).

The results obtained were used in the development of an industrial reactor (Prodmnash, Rostov-on-Don) for the torrefaction of biomass with an output of 1100 kg/h with respect to the initial biomass.

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